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National Ignition Facility Functional Requirements and Primary Criteria Evidence of Completion

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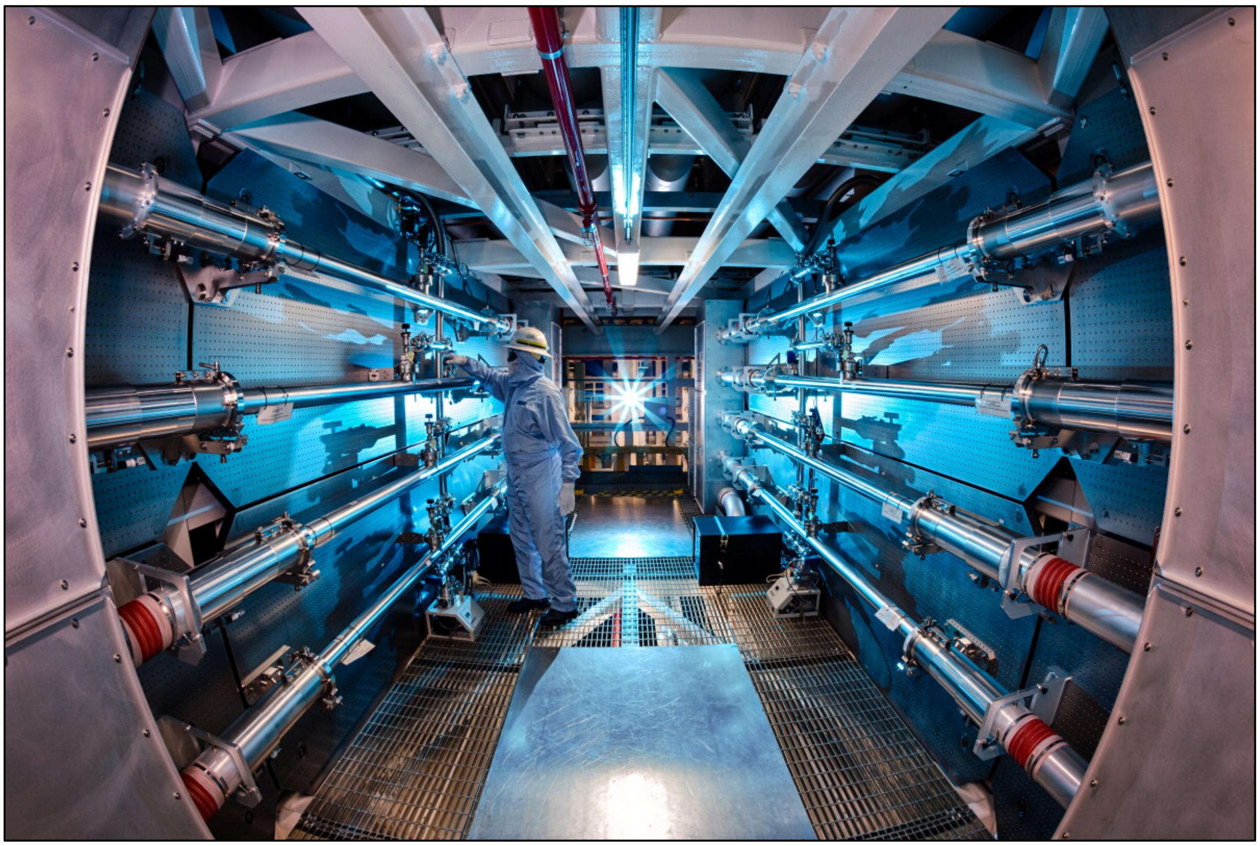

September 30, 2012

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SUMMARY

All of the National Ignition Facility (NIF) Functional Requirements and Primary Criteria (NIF FR& PCs) were accomplished prior to completion of the National Ignition Campaign (NIC). A subset of the NIF FR& PCs was completed by the NIF construction project on March 27, 2009. The remaining NIF FR& PCs were completed during the NIC ending September 30, 2012. This document provides the evidence file for completion of all of the NIF FR& PCs.

1. INTRODUCTION AND REPORT STRUCTURE

The scientific and engineering requirements for the National Ignition Facility (NIF) were established and documented in the NIF Functional Requirements and Primary Criteria (FR&PCs).[1] In the NIF FR&PCs, the mission-related requirements and goals, as defined in the NIF Justification of Mission Need, were translated into specific laser requirements such as laser energy, power, and a variety of beam characteristics. Capabilities to conduct experiments supporting the requirements of users with diverse needs and top-level operability, safety, and environmental requirements were also defined to ensure that, when completed, NIF would be operated in a manner consistent with its role as a national resource. Finally, key requirements needed to satisfy Department of Energy (DOE) Orders, state, and federal regulations, national consensus standards and preferred procedures were also highlighted in the FR&PCs to ensure incorporation by the design teams during the NIF Project.

The NNSA certified the completion of the NIF Project on March 27, 2009, with the approval of Critical Decision 4 (CD4) stating that the NIF Project had satisfied or exceeded all of the Project Completion Criteria (PCC) established in their Project Execution Plan.[2] From the point of view of laser performance, the PCC for single bundle and 96-beam laser performance had been satisfied. The need to satisfy the NIF FR&PC was not required until NIF was ramped up to full power operation following CD4.[3]

One of the objectives of the National Ignition Campaign (NIC), the scientific and technology program on NIF with the goal of achieving fusion ignition on NIF, is to transition the NIF to routine facility operations by the end 2012 and demonstrate that NIF meets its FR&PC. On July 5, 2012, NIC conducted a symmetry capsule implosion experiment with 192 NIF beams delivering 1.855 MJ of energy at a peak power of 523 TW in a precision shaped ignition pulse. This shot completed the commissioning of NIF for routine operations at its design specifications of 1.8 MJ and 500 TW.[4]

This report provides evidence of completion of the NIF FR&PCs, Rev 1.8 [0]. In accordance with Section 1.3 of the original document NIF FR&PCs (NIF-0001006-OE, September 2006), only "shall" requirements are considered as mandatory (must be met) and are addressed in this report. In text that follows, each "shall" requirement is reproduced from the original document in the order in which it appeared, followed by the evidence presented to justify completion. In some cases where several requirements point to the same piece of evidence, these requirements are grouped together. When the evidence cites specific reference material such as a document, a report, or a journal article, a number in square brackets will follow, which refers to a unique number of a file that contains the cited reference material. The reference material can be found at https://lasers2.llnl.gov/reviews/,[5] a password protected website. The numbers of the evidence files are not contiguous in some instances because some documents have been cited in multiple places.

[1] NIF-0001006-OE, September 2006.
[2] Memorandum for the Secretary (DOE) from Thomas P. D'Agostino, NNSA Administrator, Approval of CD4, dated March 24, 2009.
[3] NIF Data Sheet (page 171, section 10.1.7 Project Completion) relative to NIF Construction from the annual 2008 DOE Congressional Budget Submissions.
[4] This capability was enabled during the May 2012 NIF Facility Maintenance and Reconfiguration (FMR) period.
[5] Select Ignition Review to find cited references.

2. MISSION-RELATED REQUIREMENTS

Requirement: ***The laser system shall be designed to meet the following requirements simultaneously, although all performance requirements need not be demonstrated simultaneously on a single event.***

2.1 Laser

Requirement: ***2.1.1 Laser Pulse Energy***

The laser shall be capable of routinely producing a temporally shaped pulse of energy at least 1.8 million joules (MJ) incident on the entrance hole of the target hohlraum.

Requirement: ***2.1.2 Laser Pulse Peak Power***

The laser shall be capable of producing a pulse with peak power of at least 500 trillion watts (TW).

Requirement: ***2.1.3 Laser Pulse Wavelength***

The wavelength of the laser pulse delivered to the target shall be 0.35 microns (μm). The design should not preclude delivering 0.53-μm and 1.05-μm wavelength light to the target with reasonable modifications.

Requirement: ***2.1.4 Beamlet Power Balance***

The rms deviation in the power delivered by the laser beams from the specified power shall be less than 8% of the specified power averaged over any 2 nanosecond (ns) time interval.

Requirement: ***2.1.5 Beamlet Positioning Accuracy***

The rms deviation in the position of the centroids of all beams from their specified aiming points shall not exceed 50 micrometers (μm) at the target plane or its equivalent.

Requirement: ***2.1.6 Laser Pulse Duration***

The laser shall be capable of producing a pulse with overall duration of up to 20 ns.

Requirement: ***2.1.7 Laser Pulse Dynamic Range***

The laser shall be capable of delivering pulses to the fusion target with a dynamic range of at least 50:1, where the dynamic range is defined as the ratio of intensity at the peak of the pulse to the intensity in the initial "foot" portion of the pulse.

Requirement: ***2.1.8 Capsule Irradiation Symmetry***

Variations in the x-ray energy deposited on the fusion capsule, located in the target hohlraum, should be ≤2% rms. Current target design and performance calculations indicate that this level of irradiation uniformity can be achieved by two-sided laser illumination of the hohlraum. Multiple laser beams on each side enter the hohlraum along two concentric cones with cone half-angles of approximately 27 degrees and 53 degrees, and with two-thirds of the beams on the outer cone and the remaining one- third on the inner cone. Each cone shall consist of 8 or more beams. The capability shall be provided for the pulse shape delivered by beams on the inner cone to be different from the shape delivered by those on the outer cone.

Requirement: ***2.1.9 Pre-Pulse Power***

The laser intensity delivered to the target during the 20-ns interval prior to arrival of the main laser pulse shall not exceed 10^8 W/cm^2.

Requirement: ***2.1.10 Laser Pulse Spot Size***

Each beam shall deliver its design energy and power encircled in a 600 μm diameter spot at the target plane or its equivalent. In the appropriate configuration, each beam should deliver 50% of its design energy and power encircled in a 100-μm-diameter spot at the target plane or its equivalent.

Requirement: ***2.1.11 Beam Smoothness***

The NIF shall have spatial and temporal beam conditioning to control intensity fluctuations in the target plane.

Evidence:
The following evidence addresses the Requirements in Sections 2.0 and 2.1 through Requirement 2.1.11, Beam Smoothness, and Requirement 2.1.13, Beam Focusing and Pointing.

The path for meeting both the Project Completion Criteria (PCC) and the Functional Requirements and Primary Criteria (FR&PCs) for NIF involved system integration beginning with a single beam line and then a quad of beams to demonstrate performance capabilities, repeatability, stability, and precision control. This was followed by the integration of 96 beams at Project completion in 2009. At the end of the National Ignition Campaign (NIC) in FY2012, all 192 NIF beams integrated to reach full 1.8-MJ/500-TW performance requirements in routine operation. Two peer review committees were formed to review the NIF Laser Performance. The committee reports provide the supporting evidence that all of the laser performance requirements in the NIF FR&PC have been met.

- The first review was held as a two-part review conducted December 8-10, 2008, and February 24-25, 2009, and was chaired by Dr. M. Dunne, then Director of the Central Laser Facility, Rutherford Appleton Laser Laboratory, United Kingdom. The review focused on assessing the extent to which the NIF Project Completion Criteria (PCC) had met all of its requirements for Single Bundle and 96-Beam operation. This review used as its basis a document entitled "Summary of the evidence file demonstrating completion of NIF Project Completion Criteria (PCC)," LLNL-MI-410586, NIF-0115299-AA, dated Jan 30, 2009 [1]. A letter report to Scott Samuelson, the then NIF Federal Project Manager, dated Feb. 25, 2009 [2], confirmed that, "all laser performance (Project) completion criteria have been met or exceeded."

- A second Laser Performance Review [3], chaired by Dr. Robert L. Byer, William R. Kenan, Jr. Professor of Applied Physics at Stanford University and the current (2012) President of the American Physical Society, was held on July 24-25, 2012. The review was scheduled shortly after the July 5, 2012, symmetry capsule implosion experiment in which 192 NIF beams delivered 1.855 MJ of energy at a peak power of 523 TW in a precision shaped ignition pulse. This shot completed the commissioning of NIF for routine operations at its design specifications of 1.8 MJ and 500 TW defined in the NIF Primary Criteria and Functional Requirements (NIF-0001006-OE, September, 2006). The purpose of this review was to provide an independent assessment of the NIF Laser System performance (FR&PCs including operation at 1.8 MJ and 500 TW) and NIF's readiness to serve as a user facility to support the broad user communities for which it was designed in routine operations beginning in FY2013. It was the conclusion of Committee, documented in its report dated September 17, 2012 [3a], that "It is our opinion that the NIF laser has thus fully accomplished and exceeded its laser performance design goals as delineated in the NIF Functional Requirements and Primary Criteria."

Requirement: ***2.1.12 Direct-Drive Requirements***

Future upgrade to meet the following requirements, specific to direct-drive experiments, shall not be precluded in the baseline NIF design.

Evidence:

Not-to-preclude direct-drive requirements were based upon direct drive assumptions early in the NIF design and construction project. Access accommodations to the NIF hardware to meet these early assumptions for Direct Drive include:

- A special slot in the 3ω Integrated Optics Module (IOM) for acceptance of a second tripler—necessary for meeting the wide bandwidth demand of Direct Drive
- Space in the Pre-amplifier Module (PAM) was set aside for future use by a 2D Smoothing by Spectral Dispersion (SSD) modulator
- A special set of 24 laser entry ports were included near the equator to provide uniform spherical target illumination as specified for Direct Drive

These provisions met the original not-to-preclude requirements established during early NIF design and construction.

Requirement: ***2.1.12.1 Direct-Drive Irradiation Symmetry***

Direct-drive ICF targets shall be irradiated by three pairs of concentric cones, with mid-plane symmetry. The cone half-angles and number of beams on each cone shall be:

Direct-drive cone	**Cone half-angle (approximate)**	**Fraction of total beams**
Inner	same as indirect drive	1/6
Outer	same as indirect drive	1/3
Waist	75 degrees	1/2

Evidence:

Beam angles for NIF in the direct drive beam configuration are given in the Table 1.

Table 1. Beam angles for NIF in the direct drive beam configuration

Port	Θ	Φ	Quad	Port	Θ	Φ	Quad
1	23.5	78.75	Q15T	37 (DD)	102.5	5.62	Q13B
2	23.5	168.75	Q42T	38 (DD)	102.5	35.62	Q11B
3	23.5	258.75	Q33T	39 (DD)	102.5	65.62	Q16B
4	23.5	348.75	Q24T	40 (DD)	102.5	95.62	Q41B
9	44.5	16.29	Q14T	41 (DD)	102.5	125.62	Q46B
10	44.5	62.46	Q12T	42 (DD)	102.5	155.62	Q44B
11	44.5	106.29	Q43T	43 (DD)	102.5	185.62	Q36B
12	44.5	152.46	Q45T	44 (DD)	102.5	215.62	Q34B
13	44.5	196.29	Q35T	45 (DD)	102.5	245.62	Q31B
14	44.5	242.46	Q32T	46 (DD)	102.5	275.62	Q26B
15	44.5	286.29	Q25T	47 (DD)	102.5	305.62	Q23B
16	44.5	332.46	Q22T	48 (DD)	102.5	335.62	Q21B
25 (DD)	77.5	24.38	Q13T	57	135.5	27.54	Q14B
26 (DD)	77.5	54.38	Q11T	58	135.5	73.71	Q12B
27 (DD)	77.5	84.38	Q16T	59	135.5	117.54	Q43B

Port	Θ	Φ	Quad	Port	Θ	Φ	Quad
28 (DD)	77.5	114.38	Q41T	60	135.5	163.71	Q45B
29 (DD)	77.5	144.38	Q46T	61	135.5	207.54	Q35B
30 (DD)	77.5	174.38	Q43T	62	135.5	253.71	Q32B
31 (DD)	77.5	204.38	Q36T	62	135.5	297.54	Q25B
32 (DD)	77.5	234.38	Q34T	64	135.5	343.71	Q22B
33 (DD)	77.5	264.38	Q31T	69	156.5	11.25	Q15B
34 (DD)	77.5	294.38	Q26T	70	156.5	101.25	Q42T
35 (DD)	77.5	324.38	Q23T	71	156.5	191.25	Q33B
36 (DD)	77.5	354.38	Q21T	72	156.5	281.25	Q24B

Requirement: ***2.1.13 Beam Focusing and Pointing***

The NIF should have flexibility in beam focusing and pointing to address the needs of radiation effects testing and other users.

Evidence:
The NIF beam is nominally 37 cm square with a 7.7-m focus to target chamber center. The effective beam area is 1240 cm^2. A two-by-two group of four beams comprises a quad. These beams are located with a center–center spacing of 55.7 cm in the azimuthal direction and 63.2 cm in the polar direction. The f/# of an individual beam is 20.7. The f/# of a quad of 4 beams is 7.9.

The quads of beams enter the target chamber through ports that are located on 4 cones at 23.5, 30, 44.5, and 50 degree polar angles on the target chamber. Additional ports at 77.5 degree polar angle are designated for future use in a direct-drive configuration for NIF. A full listing of the beam port angles and cross-reference to the quad numbering is provided in Table 2.

Individual beams are pointed near chamber center by tilting the LM5 and LM8 turning mirrors. The expected range of pointing for each beam is ±30 mm up/down and ± 5 mm transverse to the beam coordinates and ±30 mm in Z (along the beam direction) about target chamber center. The goal for pointing range along the beam direction is –46 (towards the focus lens) to +38 (away from the focus lens) mm.

Beam angles for NIF in the indirect drive beam configuration are provided in the Table 2.

Table 2. Beam angles for NIF in the indirect direct drive beam configuration

Port	Θ	Φ	Quad	Port	Θ	Φ	Quad
1	23.5	78.75	Q15T	49 (ID)	130	5.62	Q13B
2	23.5	168.75	Q42T	50 (ID)	130	50.62	Q11B
3	23.5	258.75	Q33T	51 (ID)	130	95.62	Q41B
4	23.5	348.75	Q24T	52 (ID)	130	140.33	Q46B
5 (ID)	30.58	34.33	Q18T	53 (ID)	130	185.62	Q36B
6 (ID)	30	123.75	Q41T	54 (ID)	130	230.62	Q34B
7 (ID)	30.58	214.33	Q36T	55 (ID)	130	275.62	Q26B
8 (ID)	30	303.75	Q26T	56 (ID)	130	320.33	Q23B
9	44.5	16.29	Q14T	57	135.5	27.54	Q14B
10	44.5	62.46	Q12T	58	135.5	73.71	Q12B
11	44.5	106.29	Q43T	59	135.5	117.54	Q43B
12	44.5	152.46	Q45T	60	135.5	163.71	Q45B

Port	Θ	Φ	Quad	Port	Θ	Φ	Quad
13	44.5	196.29	Q35T	61	135.5	207.54	Q35B
14	44.5	242.46	Q32T	62	135.5	253.71	Q32B
15	44.5	286.29	Q25T	63	135.5	297.54	Q25B
16	44.5	332.46	Q22T	64	135.5	343.71	Q22B
17 (ID)	50	39.67	Q11T	65 (ID)	150	56.25	Q16B
18 (ID)	50	84.38	Q16T	66 (ID)	149.42	145.67	Q44B
19 (ID)	50	129.38	Q46T	67 (ID)	150	236.25	Q31B
20 (ID)	50	174.38	Q44T	68 (ID)	149.42	325.67	Q21B
21 (ID)	50	219.67	Q34T	69	156.5	11.25	Q15B
22 (ID)	50	264.38	Q31T	70	156.5	101.25	Q42T
23 (ID)	50	309.38	Q23T	71	156.5	191.25	Q33B
24 (ID)	50	354.38	Q21T	72	156.5	281.25	Q24B

By design, the NIF capabilities for beam focusing and pointing (indirect and direct drive configurations) have the flexibility to address the needs of a wide range of users including those involved with radiation effects testing.

Beam focusing and pointing was validated in the Laser Performance Review, July 24-25, 2012, chaired by Dr. Robert L. Byer, William R. Kenan, Jr. Professor of Applied Physics at Stanford University and the current (2012) President of the American Physical Society. See Report referenced after Requirement: 2.1.11.

2.2 Experimental Area

Requirement: ***The National Ignition Facility shall be operated in a manner consistent with its role as a national resource.***

Evidence:
At the end of FY2012, consistent with its role as a national resource, NIF governance was implemented, and NIF began operations as a national User Facility supporting its missions. The *NIF Governance Plan*, LLNL-AR-416565 (NIF0115829-AA) [4], defines the governance process for all NIF users and NIF management with respect to those users, including those from the NNSA Inertial Confinement Fusion (ICF) and High Yield Campaign, Science Campaigns, and other programs, Department of Defense (DoD) and other federal offices and agencies, the academic and private sector, and the international scientific community.

Requirement: ***Whenever possible, the design shall accommodate the requirements of users with diverse needs.***

Evidence:
This requirement was validated in the Laser Performance Review, July 24-25, 2012, chaired by Dr. Robert L. Byer, William R. Kenan Jr. Professor of Applied Physics at Stanford University and the current (2012) President of the American Physical Society. See Report referenced after Requirement: 2.1.11.

Requirement: ***The baseline facility design shall not preclude future addition of target chambers for additional weapons physics and/or radiation effects testing.***

Evidence:
The NIF facility was designed not to preclude the addition of a second target chamber. A proposal entitled "Enhanced NIF: Increased Fusion Yield and Target Performance Margin in Support of the SSP," LLNL-PROP-586912 [5], was submitted to NNSA in February 2012 as part of the Future Facilities competition that would exercise this option. Phase 2 of that proposal described the construction of a second target chamber to ultimately support 12 experiments/year at yields up to 500 MJ/experiment.

2.2.1 ICF Target Compatibility

Requirement: ***The target chamber and target area support systems shall be capable of target operations with both cryogenic and non-cryogenic targets containing fusion fuel.***

Evidence:
During the National Ignition Campaign that ended September 30, 2012, more than 15 exploding pusher experiments were conducted on NIF. These experiments use a thin-walled glass sphere filled with gaseous deuterium (DD) or deuterium-tritium (DT) to produce neutrons to calibrate the suite of nuclear diagnostics. These are warm targets (not cryogenically cooled) that are illuminated in a polar direct-drive configuration and fielded primarily on the Target Positioner (TARPOS). During the National Ignition Campaign than ended September 30, 2012, 37 cryogenically layered DT or THD target experiments were fielded on the cryogenic (CryoTARPOS).

Requirement: ***Provisions shall be made to accommodate and support experimenter-supplied cryostats for cryogenic targets.***

Evidence:
A *Polar Drive (PD) Ignition Campaign Conceptual Design* document, LLNL-TR-553311 [6] [6a] [6b] [6c] [7], has been written proposing to conduct PD ignition experiments on NIF. These experiments require developing and fielding a Polar Drive Ignition Target Insertion Cryostat (PD-ITIC), which would be attached to the CryoTARPOS after being inserted into the associated Load, Layering and Characterization System (LLCS). The Primary Criteria and Function Requirements for the NIF Polar Drive Ignition Target Cryostat are provided in LLNL-TR-553311, as well as in a University of Rochester, Laboratory for Laser Energetics (LLE) document, Q-NP-R-001 [available upon request from UR-LLE].

2.2.2 Annual Number of Shots with Fusion Yield for Chamber Design

Requirement: ***The NIF shall be capable of performing yield shots with total DT fusion yield of 1200 MJ/year.***

Evidence:
The *Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and* Supplemental *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (DOE/EIS-0348 and DOE/EIS-0236-S3) [8] evaluated the impacts of NIF operations at 1200 MJ/yr. The evaluation indicated that there were no significant impacts to the public or the environment. Thus, NIF is capable of performing yield shots with total DT fusion yield of 1200 MJ/year.

Requirement: ***The NIF shall be capable of performing up to 50 shots per year with a routine DT fusion yield of 20 MJ.***

Evidence:
NIF is authorized for Phase 4 Ignition Operations with High Yield (see FY2011 DOE Level 2 Milestone 4069: *Complete Contractor Readiness Assessment for High Yield [9]*). The decay radiation environment in the target bay (TB) has been evaluated, and it has been determined that re-entry into the TB would be possible within 5 – 7 days after a 20-MJ shot (see OSP 581.11 *NIF Laser System Installation, Commissioning and Operation,* Appendix L, *Radiological and Beryllium Hazards and Controls [10]*). This indicates that at least 50 – 20 MJ shots could occur each year, while allowing sufficient decay of induced radioactivity so that worker doses could be maintained as low as reasonably achievable (ALARA).

FY2011 DOE Level 2 Milestone 4069: *Complete Contractor Readiness Assessment for High Yield*

Completion Criteria: "Complete Contractor Readiness Assessment (RA) for Phase 4 operations as defined in the Safety Evaluation Report for the Safety Basis Document."

Completion documented in NIF-0117295, Letter to R. Schneider dated March 8, 2011. The review team agreed with the one LLNL self-identified pre-start finding, and NNSA concurrence on the RA report was received from Scott Samuelson. The one-pre-start finding "Complete training for Ignition Operations" has been closed. Approval has been given to enter Phase 4 of the Safety Basis Document and authorize ignition operations in B581 [9].

Requirement: ***The NIF design shall provide for life-cycle-cost-effective future addition of components that are needed only for high yield operations and are, therefore, not needed in the first one to two years of operations, such as shield doors, the Personnel and Environmental Protection Systems, and decontamination equipment.***

Evidence:
The primary scope of work conducted under the National Ignition Campaign (NIC) Work Breakdown Structure Element I.7, Personnel and Environmental Protection Systems (PEPS), was to provide the environmental and personnel safety systems and subsystems required to support high-yield operations at the National Ignition Facility (NIF). All the necessary hardware, processes and procedures, and training elements that together allow safe operations on NIF while producing nuclear yield and using tritium, depleted uranium, and beryllium comprise the PEPS. Specifically, PEPS systems that were installed and now are in routine use in NIF include:

- Forty-six shield doors. These doors, some weighing as much as five tons, provide radiation shielding for ignition experiments in and around the Target Bay and Switchyards. Each door was assembled, mounted, and filled with concrete.
- The Tritium Processing System (TPS). TPS is used to capture tritium from the target chamber exhaust streams.
- The Contamination Controls System. This system, housed in the Hazardous Materials Management Area (HMMA) provides fume hoods, glove boxes, and enclosures to manage contaminated items coming from the target chamber.
- The Radiation Monitoring System. This system provides continuous monitoring of the radiation environment in the facility.

2.2.3 Maximum Credible DT Fusion Yield

Requirement: ***The target chamber shall be designed based on routine DT fusion yield of 20 MJ, with the capability to withstand a DT fusion yield produced by a single shot of up to 45 MJ (a 45 MJ yield corresponds to 1.6 x 10^{19} neutrons).***

Evidence:
FY2010 DOE Level 2 Milestone MRT 3436: *Complete installation qualification of Personnel and Environmental Protection Systems (PEPS) for first ignition experiments [11]*

Completion Criteria: "This milestone will be considered complete when systems required for experiments that produce up to 20 MJ of thermonuclear yield per shot, including shield doors and area neutron and gamma monitors, are installation qualified (IQ)."

Completion has been documented in NIF-0116773, Letter from Moses to Schneider, dated September 30, 2010.

2.2.4 Classification Level of Experiments

Requirement: ***The facility shall be designed to allow both classified (at the SRD level) and unclassified experiments.***

Evidence:
FY2012 DOE Level 2 Milestone MRT 4122: *Provide classified operations capability [12]*

Completion Criteria: "A Classified Control Room is operational in NIF and is supported by infrastructure that allows Classified Data Acquisition."

Completion has been documented in NIF-0117851, Letter from Moses to Quintenz, dated December 12, 2011.

2.2.5 Target Positioner

Requirement: ***The target positioner shall be capable of placing and holding targets within 3 cm of target chamber center, with accuracy, repeatability, and stability consistent with the relative laser/target alignment specified in Section 2.1.5 and operations specified in Section 2.2.1.***

Evidence:
FY2012 NIC EP Level 2 Milestone 4116: *Demonstrate operations of two cryogenic target positioners [13]*

Completion Criteria: "Demonstrate the operation of two cryogenic target positioners, one with and one without layering capabilities."

Completion has been documented in NIF-0117849 Letter from Moses to Quintenz, dated December 12, 2011.

2.2.6 Time Between Shots with No Fusion Yield

Requirement: ***To address the needs of indirect-drive, direct-drive, and other users, the laser and experimental area shall be capable of conducting no fusion yield experiments with a time between shots of 8 hours, with a goal of 4 hours.***

Evidence:
There are many examples in which the time between system shots on NIF was less than 8 hours.

Table 3 below notes some of these. In addition, from February 1 through March 20, 2011, 34 non-ignition target shots for the High Energy Density Stewardship Science program were successfully executed in 27 shot days**.** Usually the time limiting factor related to executing a shot is not the laser turn-around time, but rather the time to load and align the target and the associated diagnostic systems or the time to reconfigure the facility (e.g. from no yield to a potentially high yield experiment or change out diagnostics for different classes of experiments).

Table 3. Example of NIF system shots where the time between shot was less than 8 hours.

Shot Number	Experiment ID	# Beams to TCC	TCC Energy (kJ 3ω)	TCC Peak Power (TW 3ω)	System Shot Time	Time Between Shots (h)
N110308-004	UU_NIFEOS_C_30Mbar_S08f	176	470	94	3/8/2011 22:54	
N110309-001	DrD_Scattered_Light_S49a	179	698	358	3/9/2011 5:24	6.5
N110501-006	Tab8_Crystal_Condition_S03b	184	705	223	5/2/2011 1:20	
N110502-002	Tab8_Crystal_Condition_S04c	184	855	268	5/2/2011 8:39	7.3
N110502-007	Tab8_Crystal_Condition_S05c	184	1029	325	5/3/2011 2:56	
N110503-001	Tab8_Crystal_Condition_S06a	176	1101	348	5/3/2011 9:25	6.5
N110504-007	LPOM_3w_Calibration_P2_S03c	192	205	44	5/5/2011 1:08	
N110505-001	LPOM_3w_Calibration_P2_S01d	180	696	361	5/5/2011 6:54	5.8
N120602-001	500TW_TCC_2012_NIF_P2 _S09a	183	620	228	6/2/2012 9:39	
N120602-002	500TW_TCC_2012_NIF_P2 _S10a	183	746	280	6/2/2012 17:13	7.6
N120602-003	500TW_TCC_2012_NIF_P2_S13 a	192	39	1	6/3/2012 0:15	7.0
N120603-001	500TW_TCC_2012_NIF_P2_S02 a	192	299	39	6/3/2012 6:29	6.2

This table only includes system shots with ≥176 Beams fired to TCC

In addition, the United Kingdom's Shot Rate Enhancement Program (SREP) on NIF which was conducted between 2000 and 2004 demonstrated:

- The NIF shot period goal of 4 hours or less can be achieved with room temperature gas cooling and;
- Achievement of acceptable optical performance under sustained shot-rate conditions at shot periods of 4, 2.5 and 1.5 hours.

Amplifier cooling gas temperature data acquired under SREP demonstrating SREP goals is shown in Figure 2.

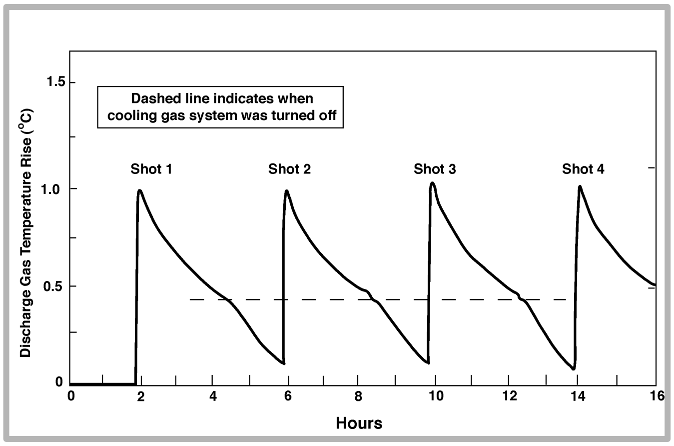

Figure 2. Temperature measurement of the amplifier cooling gas for four shots, with a four-hour shot cycle during which the amplifier cooling system was on for 2.5 hours per cycle, meeting the shot rate goal of four hours or less

2.2.7 Target Chamber Vacuum Capability

Requirement: ***The target chamber shall be capable of achieving a vacuum level of <1 x 10^{-5} Torr.***

Evidence:
The Target Area Vacuum System was commissioned in 2003. The commissioning was documented in the Target Area Vacuum System (Phase C) Commissioning Test Procedure, NIF-5011742-0A, NIFOPS-TGB-COM-013, NWBS-N.U.2.1, dated 04/02/03 [14]. The Target Chamber (TC) vacuum is verified to be less than 5 x10^{-5} Torr before each shot to the target chamber. This is done as part of the Lead Operators shot checklist, NIF-5016158-OT. The demonstration of satisfying the <1 x10^{-5} Torr requirement can be seen from a sample trend from the data logger for TC pressure shown below. In Figure 1, the top two traces, blue and red, are pressure instruments for the vacuum chamber. Spikes shown in the graph occur when valves connected to the target chamber are open/closed such as those associated with Final Optics Assemblies (FOAs) or diagnostics.

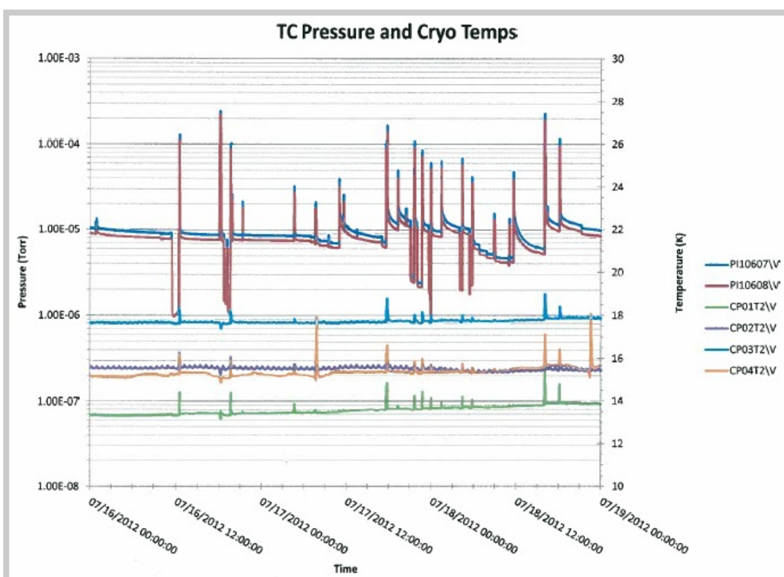

Figure 1. Graph of the Target Chamber pressure (Torr) as a function of time between July 16 and July 19, 2012, shows that the pressure is routinely less than the requirement of 1 x 10^{-5} Torr

2.2.8 Diagnostic Instrument Capabilities to Verify Laser Performance

Requirement: ***The facility shall have the following measurement capabilities that are required to verify the Primary Criteria and Functional Requirements:***

- Laser pulse energy and power
- Laser pulse duration and dynamic range
- Laser beam power balance
- Simultaneity of arrival of pulses from individual beamlines at target chamber center with 10-ps accuracy
- Laser beam pointing accuracy with 10–20 micron spatial resolution
- Laser prepulse intensity
- Laser pulse spot size
- Laser pulse smoothness
- Laser beam thermal recovery time

Evidence:
Table 4 shows a list of the laser diagnostic measurements made on each NIF shot.

Table 4. List of laser diagnostic measurements made on each NIF shot.

Measured Quantity	Instrument	Location	No. of Measurements
3ω energy	Calorimeter	FOA	192
3ω power	Diode array	FOA	48
3ω nearfield	Camera	FOA	8
1ω energy	Calorimeter	Output sensor	192
1ω power	Diode array	Output sensor	96
1ω nearfield	Camera	Output sensor	192

Each of the 192 beamlines is equipped with a drive diagnostic that measures the 3ω pulse exiting the NIF final optics upstream of the target.

These capabilities were covered in the two Laser Performance Reviews conducted on:

- December 8-10, 2008 and February 24-25, 2009, and chaired by Dr. M. Dunne, Director of the Central Laser Facility, Rutherford Appleton Laser Laboratory, United Kingdom [1]
- July 24-25, 2012 and chaired by Dr. Robert L. Byer, William R. Kenan, Jr. Professor of Applied Physics at Stanford University and the current (2012) President of the American Physical Society [3].

2.2.9 Diagnostic Instrument Capabilities for Ignition and Applications Experiments

Requirement: ***The target chamber and area shall be capable of accommodating diagnostic instruments for the following measurements necessary for fusion ignition and applications experiments:***

- Symmetry of x-ray emission from imploded cores with 5- to 10-micron spatial resolution
- Motion of the x-ray emitting volumes in hohlraums with 20 micron spatial resolution
- Laser light backscattered into the focusing lens
- Radiation flux out of hohlraums within the photon energy range 0.15–2.5 keV with 100-ps time resolution and 20% accuracy
- Strength of radiation driven shocks with 5- to 10-micron resolution and time resolution of 10 ps
- Fusion yield over a range from 10^{11} to 10^{19} neutrons

- Symmetry of neutron emission from imploded cores with 20-micron spatial resolution
- Temperature of the compressed fusion fuel with 20% accuracy for ion temperatures of 2 keV or greater
- Number and energy distribution of fast electrons in hohlraums in the band from 5 keV to 300 keV
- Radiation flux out of hohlraums within the photon energy range 2.5–100 keV with 20% accuracy

Evidence:

- **Symmetry of x-ray emission from imploded cores with 5- to 10-micron spatial resolution**.
  - Modal symmetry of imploded capsules is measured to an accuracy of a few microns with Gated X-ray Detectors (GXDs)
    - Measuring symmetry of implosions in cryogenic hohlraums at the NIF using gated x-ray detectors; G. A. Kyrala, S. Dixit, S. Glenzer, D. Kalantar, D. Bradley et al.; Rev. Sci. Instrum. 81, 10E316 (2010) [15]

- **Motion of the x-ray emitting volumes in hohlraums with 20 micron spatial resolution**.
  - Static X-ray Imager (SXI) measures position of x-ray emission in the hohlraum and laser entrance hole closure to an accuracy of 20 micron
    - Images of the laser entrance hole from the static x-ray imager at NIF; M. B. Schneider, O. S. Jones, N. B. Meezan, J. L. Milovich, R. P. Town et al.; Rev. Sci. Instrum. 81, 10E538 (2010) [16]

- **Laser light backscattered into the focusing lens**.
  - Measured by the Full Aperture Backscatter System (FABS) and Near backscatter Imager (NBI)
    - Calibration of initial measurements from the full aperture backscatter system on the National Ignition Facility; R. K. Kirkwood, T. Mccarville, D. H. Froula, B. Young, D. Bower, N. Sewall et al; Rev. Sci. Instrum. 75, 10, 4174 (2004) [17]
    - Backscatter measurements for NIF ignition targets; J. D. Moody, P. Datte, K. Krauter, E. Bond, P. A. Michel et al.; Rev. Sci. Instrum. 81, 10D921 (2010) [18]

- **Radiation flux out of hohlraums within the photon energy range 0.15–2.5 keV with 100-ps time resolution and 20% accuracy.**
  - Soft X-ray spectrometer - Dante
    - Dante soft x-ray power diagnostic for National Ignition Facility; E. L. Dewald, K. M. Campbell, R. E. Turner, J. P. Holder, O. L. Landen, S. H. Glenzer,et al; Rev. Sci. Instrum. 75, 10, 3759 (2004) [19]
    - The first measurements of soft x-ray flux from ignition scale Hohlraums atthe National Ignition Facility using DANTE; J. L. Kline, K. Widmann, A. Warrick, R. E. Olson, C. A. Thomas et al.; Rev. Sci. Instrum. 81, 10E321 (2010) [20]

- **Strength of radiation driven shocks with 5- to 10-micron resolution and time resolution of 10 ps**.
  - Velocity Interferometer System for Any Reflector (VISAR)
    - Line-imaging velocimeter for shock diagnostics at the OMEGA laser facility, P. M. Celliers, D. K. Bradley, G. W. Collins, and D. G. Hicks, T. R. Boehly and W. J. Armstrong, Rev. Sci. Instrum. 75, 4916 (2004) [21]
    - Demonstration of the shock-timing technique for ignition targets on the National Ignition Facility, Boehly, TR; Munro, D; Celliers, PM; Olson, RE; Hicks, DG; Goncharov, VN;

Collins, GW; Robey, HF; Hu, SX; Morozas, JA; Sangster, TC; Landen, OL; Meyerhofer, DD; Phys Plasmas, 16, 056302 (2009) [22]
    - Shock timing experiments on the National Ignition Facility: Initial results and comparison with simulation, H. F. Robey, T. R. Boehly, P. M. Celliers, J. H. Eggert, D. Hicks et al., Phys. Plasmas 19, 042706 (2012) [23]
    - Two-dimensional imaging velocity interferometry: Data analysis techniques, David J. Erskine, R. F. Smith, C. A. Bolme, P. M. Celliers, and G. W. Collins; Rev. Sci. Instrum. 83, 043116 (2012) [24]

- **Fusion yield over a range from 10E11 to 10E19 neutrons**.
  - Neutron Activation of detectors (In, Zr, Cu) and Neutron Time of Flight (nTOF)
    - Absolute calibration method for laser megajoule neutron yield measurement by activation diagnostics; Olivier Landoas, Vladimir Yu Glebov, Bertrand Rossé, Michelle Briat, Laurent Disdier et al.; Rev. Sci. Instrum. 82, 073501 (2011) [25]
    - The National Ignition Facility neutron time-of-flight system and its initial performance; V. Yu. Glebov, T. C. Sangster, C. Stoeckl, J. P. Knauer, W. Theobald et al.; Rev. Sci. Instrum. 81, 10D325 (2010) [26]
    - National Ignition Facility neutron time-of-flight measurements; R. A. Lerche, V. Yu. Glebov, M. J. Moran, J. M. McNaney, J. D. Kilkenny et al.; Rev. Sci. Instrum. 81, 10D319 (2010) [27]

- **Symmetry of neutron emission from imploded cores with 20-micron spatial resolution**.
  - Neutron Imager (NI)
    - The National Ignition Facility Neutron Imaging System; Mark D. Wilke, Steven H. Batha, Paul A. Bradley, Robert D. Day, David D. Clark et al.; Rev. Sci. Instrum. 79, 10E529 (2008) [28]
    - Development of the large neutron imaging system for inertial confinement fusion experiments; T. Caillaud, O. Landoas, M. Briat, S. Kime, B. Rossé et al.; Rev. Sci. Instrum. 83, 033502 (2012) [29]
    - Progress toward the development and testing of source reconstruction methods for NIF neutron imaging; E. N. Loomis, G. P. Grim, C. Wilde, D. C. Wilson, G. Morgan et al.; Rev. Sci. Instrum. 81, 10D311 (2010) [30]
    - Modeling the National Ignition Facility neutron imaging system; D. C. Wilson, G. P. Grim, I. L. Tregillis, M. D. Wilke, M. V. Patel et al.; Rev. Sci. Instrum. 81, 10D335 (2010) [31]

- **Temperature of the compressed fusion fuel with 20% accuracy for ion temperatures of 2 keV or greater**.
  - Neutron Time of Flight (nTOF) to a few percent
    - The National Ignition Facility neutron time-of-flight system and its initial Performance; V. Yu. Glebov, T. C. Sangster, C. Stoeckl, J. P. Knauer, W. Theobald et al.; Rev. Sci. Instrum. 81, 10D325 (2010) [32]
    - National Ignition Facility neutron time-of-flight measurements; R. A. Lerche, V. Yu. Glebov, M. J. Moran, J. M. McNaney, J. D. Kilkenny et al.; Rev. Sci. Instrum. 81, 10D319 (2010) [27]

- **Number and energy distribution of fast electrons in hohlraums in the band from 5 keV to 300 keV**.
  - Filter-fluorescer diagnostic system (FFLEX)

- Filter-fluorescer diagnostic system for the National Ignition Facility; J. W. McDonald, R. L. Kauffman, J. R. Celeste, M. A. Rhodes, F. D. Lee,J. Suter, and A. P. Lee; Rev. Sci. Instrum. 75, 10 3753 (2004) [33]
- Characterizing high energy spectra of NIF ignition Hohlraums using a differentially filtered high energy multipinhole x-ray imager; Hye-Sook Park, E. D. Dewald, S. Glenzer, D. H. Kalantar, J. D. Kilkenny et al.; Rev. Sci. Instrum. 81, 10E519 (2010) [34]

- **Radiation flux out of hohlraums within the photon energy range 2.5‒100 keV with 20% accuracy**
  - A combination of Dante and FFLEX provide this diagnostic capability (see references above)

Control System publication:

- Target diagnostic control system implementation for the National Ignition Facility; R. T. Shelton, J. H. Kamperschroer, L. J. Lagin, J. R. Nelson, and D. W. O'Brien; Rev. Sci. Instrum. 81, 10E101 (2010) [35]

2.2.10 Removal and Replacement of Diagnostic Instruments

Requirement*: Rapid removal and replacement of diagnostic instruments consistent with the shot frequency specified in Section 2.2.6 shall be accomplished by diagnostic inserters and manipulators for close-in target diagnostics.*

Evidence:

Diagnostic Instrument Manipulators (DIMs) are two stage telescoping devices capable of inserting, retracting, positioning and aligning a diagnostic instrument in the Target Chamber, from the interior wall to the Target Chamber Center. Currently, NIF is equipped with three DIMs. DIMs can be fit to a number of designated target chamber diagnostic ports, but are currently mounted: one on the Target Chamber pole and two on its equatorial plane. The DIMs also provide a standard set of utilities and cables to support operation of all DIM-based diagnostic instruments. The capabilities of the DIMs on the NIF target chamber can be found in DIM-based Diagnostic Design Guidance for the NIF, NIF-5041482 issued June 29, 2012 [36]).

2.2.11 Personnel Access Inside the Target Chamber

Requirement: ***Personnel access to the inside of the target chamber shall be consistent with requirements for periodic cleaning necessary to maintain radiological, low-hazard, non- nuclear operations and for inspection and maintenance consistent with operational requirements.***

Evidence:

The Target Chamber Service System (TCSS) consists of mechanical, electrical and hydraulic motion control systems and actuators that enable one or two people to be positioned anywhere within the target chamber interior via a boomlift for the purposes of cleaning, installation and maintenance of the target chamber first walls and other equipment inside the target chamber. The TCSS is operational and available for use to support inspection, maintenance, equipment installation, and facility reconfiguration as necessary. The pertinent documents verifying the capability for personnel access to the inside of the NIF Target Chamber are:

- TCSS Test Plan, NIF-00915022. TCSS Acceptance Test Package, PaR Systems Document No. 68899108 [36a]
- TCSS Boom MPR Report [36b]

3. SAFETY REQUIREMENTS

Requirement: ***The NIF shall be designed, constructed, and operated as a radiological low-hazard facility.***

Evidence:
This is documented in the Tier 2 Safety Basis Document for the Building 581-582 Complex, NIF-5019666 [37].

Requirement: ***This classification shall be established through a Preliminary Hazard Analysis assessment of bounding accidents involving those radionuclides and/or chemicals presenting the most significant hazards.***

Evidence:
The original Preliminary Hazards Analysis has been superseded by the current safety basis document, the Tier 2 Safety Basis Document for the Building 581-582 Complex, NIF-5019666 [37].

Requirement: ***Administrative controls shall be established prior to the first use of tritium-bearing targets to ensure that inventory limits for a radiological low-hazard facility are not exceeded.***

Evidence:
The *Safety Basis Administrative Controls Configuration Items* list, NIF-5021154 [38], identifies the flow down of administrative safety basis limits such as inventory limits. Tritium inventory limits are implemented through the *Facility Safety Plan for Buildings 581/582, 682, 683, and 684,* NIF-5019665 [39], *NIF Laser System Installation, Commissioning and Operation, Operational Safety Plan OSP581.11,* NIF-5017298 [7], and the Radiological Inventory Management System (RIMS) (*Radiological Inventory Management Procedure,* NIF-5029375 [41], and *RIMS Software Requirements Specification,* NIF-5029982) [42].

3.1 Radiation Protection

Requirement: ***Collective and individual ionizing radiation doses to the public from all exposure pathways from the NIF shall meet the requirements of DOE Order 5400.5, Radiation Protection of the Public and the Environment, and 40 CFR 61, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities.***

Evidence:
The Final Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement, DOE-EIS-0348/DOE-EIS-0236-S3 [5], documents the expected bounding impacts from NIF operations and shows that the public dose from all exposure modes and all sources of radiation does not exceed the requirements of DOE Order 5400.5 (now replaced by DOE Order 458.1). Projected bounding airborne radiological emissions from the NIF are documented in NESHAPS Evaluation of the National Ignition Facility, EMAD09-018 [44], showing compliance with 40 CFR 61, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities. In addition, actual emissions, which are far below this, are reported in the LLNL Annual Environmental Report. The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 [46] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725 [47]) and the Ignition

Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement: ***These requirements state that exposure of members of the public from emissions of radionuclides in the ambient air from normal NIF operations shall remain below 10 mrem/y.***

Evidence:
Projected bounding airborne radiological emissions from the NIF are documented in *NESHAPS Evaluation of the National Ignition Facility*, EMAD09-018 [44], showing that they are below 10 mrem/y and that they are in compliance with 40 CFR 61, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities. In addition, actual emissions, which are far below this, are reported in the *LLNL Annual Environmental Report*. The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 [46] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725 [47]) and the Ignition Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement: ***The facility shall also meet the requirements of DOE Order 5400.5 to not cause the public dose from all exposure modes and all sources of radiation at the site boundary to exceed 100 mrem/y.***

Evidence:
The *Final Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement*, DOE-EIS-0348/DOE-EIS-0236-S3 [5], documents the expected bounding impacts from *NIF* operations and shows that the public dose from all exposure modes and all sources of radiation do not exceed 100 mrem/yr at the site boundary. The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 [46] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725 [47]) and the Ignition Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement: ***The NIF personnel radiation protection program shall follow DOE Order N441.2 Radiation Protection for Occupational Workers and 10 CFR 835, Occupational Radiation Protection.***

Evidence:
The NIF personnel radiation protection program is documented in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation*, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7], and ES&H Manual Document 20.1 [54], *Occupational Radiation Protection,* Document 20.2 [55], *LLNL Radiological Safety Program for Radioactive Materials,* and Document 20.3 [56]. The NIF personnel radiation protection was reviewed and determined to meet requirements during two Management Prestart Reviews on the introduction of tritium, beryllium, depleted uranium, and low-yield operations [46, 47], and *during* the Ignition Readiness Assessment [48]. Further, DOE-HQ (EM and OH) reviewed the NIF Radiation Protection Program in May 2011 and found it to be satisfactory. Note that N441.2 is obsolete (it has been incorporated into 10CFR835). The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 [46] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725

[47]) and the Ignition Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement: ***The ALARA (as low as reasonably achievable) principle shall be utilized in both design and operation of the facility to eliminate unnecessary radiation dose to workers in the Laser and Target Area Building, collocated employees, and visitors from both routine and off-normal operations.***

Evidence:
The ALARA principle is invoked in design and operation of the NIF through OSP 581.11, *NIF Laser System Installation, Commissioning and Operation*, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7]. Worker Dose is managed through *NIF ALARA Planning Process*, NIF-5031980 [62]. The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 [46] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725 [47]) and the Ignition Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement***: Radiation protection shall include: shielding; control of workplace ventilation; monitoring of personnel for external and internal radiation dose; establishment of a routine contamination monitoring program including air monitoring; and the proper containment of radiation and radioactive materials.***

Evidence:
Required shielding and associated shielding analysis is identified on the *Radiation Shielding Configuration Items* list, NIF-5017063 [66]. Equipment required for the control of workplace ventilation is identified in the *Contamination Control Systems Configuration Items* list, NIF-5024887 [67], and the *Ventilation System Configuration Items* List, NIF-5016685 [68].

Required internal and external dosimetry is identified in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation,* Appendix L, *Radiological and Be Hazards and Controls,* NIF-5017298 [7]. Routine contamination monitoring is delineated in the *ES&H Team 2 Health Physics Discipline Action Plan for NIF Site [70].* In addition to specific work place air monitoring identified in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation*, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7], the fixed radiation monitors at the NIF are identified on the *Radiation Monitors Configuration Items* list NIF- 5026091 [71]. Equipment required for the containment of radiation and radioactive materials is identified on the *Confinement Envelope Configuration Items* list, NIF-5017724 [72]. The Radiation Protection Program was validated in two Management Prestart Reviews (Readiness to Introduce Tritium for Cryolayering Management Prestart Review, NIF-0116557 73] and Beryllium, Depleted Uranium, Tritium, and Low Yield Operations Management Prestart Review, B581, NIF-0116725 [47]) and the Ignition Readiness Assessment (National Ignition Facility, Ignition Readiness Assessment Final Report, NIF-0117362 [48]).

Requirement: ***Concrete shielding shall comply with ACI 301, which provides adequate strength for design basis earthquake (DBE) loads.***

Evidence:
The following requirements *were* provided to the Architecture and Engineering firm and incorporated into the designs for the building, conventional facilities, process utilities, and shield doors.

- NIF Package 6, OCS-0075, Section 03300, Cast-in-Place Concrete [76]

- NIF QA Shield Door Thickness Verification – 100408bw.PDF [76a]
- NIF QA Strength and Density Data 100112bw.pdf [76b]

These requirements *were* also incorporated into the design's beampath infrastructure:

- American Concrete Institute, ANSI/ACI-301
- Association of State Highway Transportation Officials (AASHTO).

Requirement: ***The target chamber and tritium processing systems shall form the primary confinement barrier.***

Evidence:
The primary confinement barriers are identified on the *Confinement Envelope Configuration Items* list, NIF-501772 [72] (which includes the target chamber), and on the *Contamination Control Systems Configuration Items* list, NIF-5024887 [67] (which includes the tritium processing system).

Requirement*: Leakage past these barriers shall be ALARA.*

Evidence:
Leakage from elements of the confinement envelope and contamination control systems is maintained ALARA through a routine maintenance program. Leak checking and leak rate requirements for elements of the Confinement Envelope are identified in *Configured System Maintenance Plan, Confinement Envelope System*, NIF-5022445 [78]. Leak inspection requirements for elements of Contamination Control Systems are identified in *Configured System Maintenance Plan, Confinement Envelope System*, NIF-5022445 [78].

Requirement: ***The experimental-area ventilation system shall be designed to operate at negative pressures during and immediately after shots of greater than one megajoule and provide secondary tritium confinement.***

Evidence:
The pressure requirements for the Target Bay and the equipment necessary to provide the confinement capability are identified on the *Ventilation System Configuration Items* list, NIF-5016685 [68]. The requirement to invoke this capability ("confinement mode") for Category C shots (> ~ 30 kJ) is stated in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation,* Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7].

Requirement: ***The final exhaust release point from this system should be elevated for dispersion. Exhaust air shall be continuously monitored for radioactivity.***

Evidence:
The elevated release point is identified on the *Ventilation System Configuration Items* CI list, NIF-5016685 [68], and can also be verified by observation; the stack monitor is identified on the R*adiation Monitors Configuration Items* List, NIF-5026091 [71].

Requirement: ***The target area shall also be monitored to ensure that radiological conditions are safe for personnel entry.***

Evidence:
Target Bay radiation monitors are identified on the *Radiation Monitors Configuration Items* list, NIF-5026091 [71]; the re-entry process is described in OSP 581.11, *NIF Laser System Installation,*

Commissioning and Operation, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7].

3.2 Life Safety

Requirement: ***The NIF shall fully comply with the requirements for life safety contained in all National Fire Protection Association (NFPA) Codes.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis*, dated March 31, 2011, Section 7 [84].

Requirement: ***Particular focus shall be directed towards features related to the means of egress, such as protection of vertical openings, travel distances, capacities, and emergency lighting.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis*, dated March 31, 2011, Section 7 [84].

3.3 Laser Safety

Requirement*: The laser safety shall comply with ANSI Z136.1.*

Evidence:
This is implemented through the *LLNL Environmental Safety& Health (ES&H) Manual Document* 20.8 [85] and the *Operational Safety Procedure (OSP) 581.11* [10]. The Laser Safety Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

Requirement: ***Exposure to hazardous levels of laser light shall be prevented by the use of physical barriers, personnel training, interlocks, and personnel entry controls.***

Evidence:
Physical barriers providing protection from laser light are identified on the *Laser Safety Configuration Items* list, NIF- 5018076 [88]; the interlocks providing protection from laser light are identified on the *Safety Interlock System Configuration Items* list, NIF-5016337 [89]; required laser safety training and personnel entry controls as well as Lockout/Tagout procedures are specified in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation [7]*. The Laser Safety Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

Requirement: ***Protective equipment, such as laser goggles, shall be used when necessary for operational purposes.***

Evidence:
Personal Protective Equipment (PPE), such as laser goggles, required to mitigate laser light hazards is specified in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation [7]*. The Laser Safety Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

Requirement: ***Interlock systems shall be dedicated and designed to be fail-safe and shall activate laser shutters or shut off power to laser systems if access doors are opened and hazardous exposures are possible.***

Evidence:
The *Safety Interlock System Configuration Items* list, NIF-5016337 [89], identifies the interlock

hardware to provide this functionality. The Laser Safety Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

3.4 Industrial Hygiene and Occupational Safety

Requirement: ***Industrial hygiene and occupational safety shall comply with 29 CFR 1910 Occupational Safety and Health Act (OSHA) - Operation.***

Evidence:
The following documents provide evidence for satisfying this requirement:

- *NIF&PS Directorate Subcontractor Safety Manual* – NIF-5030733 [92]
- *National Ignition Facility Project – Transition to Operations Plan* approved by the Office of Inertial Confinement Fusion and the National Ignition Facility Project, NA-123 [93]
- *National Ignition Facility Project Completion Report* – NIF-0115688 [94]
- *NIF&PS Directorate Safety Manual* – NIF-5032483 [95]

Requirement: ***Facility subsystems (e.g., capacitor banks, vacuum systems, tritium recovery, nitrogen supply, and personnel safety interlock systems) shall be designed to default to a safe state upon loss of power.***

Evidence:
The redundant, fail-safe design of the Power Conditioning System (capacitor banks) is described in section 1.4.8 of the PCS Design Basis Document (NIF-5018618) [97] and section 5.2.4.3 of the PCS EE Safety Note (NIF-5017604) [98].

Target Chamber Vacuum System - System Level Maintenance Plan, NIF-5018577 [99], and *Diagnostic Vacuum Systems - System Level Maintenance Plan* NIF-5018567 [100] describe how the vacuum systems fail to a safe state upon loss of power. This is also described in the *Confinement Envelope FMEA*, NIF-5022473 [101], and in the *Modifications to the Target Area Vacuum System FMEA*, NIF-5026251 [102].

The *Tritium Processing System FME*A, NIF-5026030 [103], describes how the TPS fails to a safe state upon loss of power.

For the most part, the LN system operates without electric power. Control power is used by the 4 FV valves, which isolate LN from the TC cryo pumps. The *System Level Maintenance Plan for the Target Chamber Vacuum System*, NIF-5018577 [99], indicates that these valves fail to a safe state upon loss of power.

The fail-safe response of the Safety Interlock System upon loss of power is documented in the *SIS FMEA*, NIF-5015775 [105].

3.5 Fire Protection

Requirement: ***The NIF shall meet the design and fire protection requirements, all NFPA Codes and the Uniform Building Code (UBC).***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 1.5 and Section 13 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness

Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

Requirement: ***The structural members of the Experimental Building (including exterior walls, interior bearing walls, columns, floors, roofs, and supporting elements) shall, as a minimum, meet UBC fire-resistive standards.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 1 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

Requirement: ***Appropriate fire barriers shall be provided to limit property damage, fire propagation, and loss of life by separating adjoining structures, isolating hazardous areas, and protecting egress paths.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 1.5 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

Requirement: ***The NIF shall meet the requirements for an "improved risk" level of fire protection sufficient to attain DOE objectives.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 13 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

Requirement: ***To achieve this level of protection, automatic fire sprinklers shall be installed throughout the complex.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 3.1 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

Requirement: ***The sprinklers shall be coupled with adequate fire protection water supplies and automatic and manual means for detecting and reporting incipient fires.***

Evidence:
This is addressed in the *B581 Fire Hazards Analysis* dated March 31, 2011, Section 3.9 and 4 [84]. The Fire Protection Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87], and The NNSA Readiness Assessment of Routine Integrated Facility Operations at the NIF, NIF-0135484 [108].

3.6 Robotic Systems Safety

Requirement*: **Robotic systems shall comply with the requirements of ANSI/RIA R15.06–1992; Industrial Robots and Robot System—Safety Requirements.***

Evidence:
NIF presently has no robotic systems. The transporters used for laser LRU installations were designed based on ANSI B56.5 Safety Standard for Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles. This is appropriate since these units are guided industrial vehicles, not robots.

4. ENVIRONMENTAL PROTECTION

4.1 Waste Management

Requirement: ***The NIF shall minimize the generation of wastes at the source per: DOE Policy P450.1, Environmental Safety and Health Policy for the Department of Energy Complex, General Environmental Protection Program, and DOE Order 5820.2A, Radioactive Waste Management; and the Resource Conservation and Recovery Act (USC 6901 to 6992); and the Toxic Substances Control Act (USC 2601-2692).***

Evidence:
The NIF developed a *Pollution Prevention and Waste Minimization Plan,* NIF-0010575 [109], during the design to ensure pollution prevention and waste minimization concepts were incorporated. Ongoing expectations regarding waste minimization are described in *Facility Safety Plan for Buildings 581/582, 682, 683, and 684*, NIF-5019665 [39] and OSP 581.11, *NIF Laser System Installation, Commissioning and Operation*, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7].

Requirement: ***The NIF waste handling areas shall comply with the standards of confinement and ventilation requirements specified by DOE Order 5820.2A, Radioactive Waste Management.***

Evidence:
Negative pressure/ventilation is provided in areas of the facility (e.g., Target Bay, Hazardous Materials Management Area) where the potential exists for the generation of airborne radioactive or hazardous contaminants. This includes areas of the facility where wastes could be generated/handled. Equipment required for the control of workplace ventilation is identified in the *Contamination Control Systems Configuration Items* list, NIF-5024887 [67], and the *Ventilation System Configuration Items* List, NIF-5016685 [68].

Requirement: ***These wastes shall be collected in approved containers, labeled, packaged, sorted, and shipped to an EPA/DOE-approved treatment or disposal site according to the Resource Conservation Recovery Act and the following regulations: hazardous waste per 40 CFR 260, 261 and 262; low-level waste per DOE Order 5820.2A; and mixed (LLW and hazardous) waste per DOE Order 5820.2A, and 40 CFR 260.***

Evidence:
NIF Waste Management Practices are described in *Low-Level Radioactive Waste Management Plan*, NIF-5035809 [114]. This document includes expectations on approved containers, labeling, and packaging. NIF wastes are shipped to the onsite Waste Management Facility, and then to the Nevada Test site, which is a DOE-approved disposal site. The Waste Management Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

Requirement: ***The LLW packages shall meet the radioactive solid waste acceptance criteria of the final approved disposal site. Pollution prevention will be considered in the NIF design as required by DOE Order 430.1.***

Evidence: NIF Waste Management Practices are described in *Low-Level Radioactive Waste Management Plan*, NIF-5035809 [114], which implements the waste acceptance criteria of the Nevada Test Site (NNSS WAC) through the *LLNL Waste Certification Program,* WCP-8. The NIF developed a *Pollution Prevention and Waste Minimization Plan*, NIF-0010575 [109], during the design to ensure pollution prevention and waste minimization concepts were incorporated. The Waste Management Program was validated in the National Ignition Facility Project Readiness Assessment, NIF-0118276 [87].

4.2 Effluents

Requirement: ***Liquid effluent discharges from NIF discharge points shall be monitored and controlled in compliance with 10 CFR 835, DOE Order 5400.5, Radiation Protection of the Public and the Environment; the Clean Water Act (33 U.S.C. 1251 et seq.); and by conditions on 40 CFR 125 Criteria and Standards for National Pollutant Discharge Elimination System.***

Evidence:
Liquid effluents are few and originate in the Hazardous Materials Management Area. Controls for liquid effluents are specified in OSP 581.11, *NIF Laser System Installation, Commissioning and Operation,* Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7] and *Operation of the Hazardous Material Management Area (HMMA) Wash and Wastewater Systems*, NIF-5030974 [117]. The configuration of retention tanks and berms used to control liquid effluent discharges are assured as described in the *Configured System Maintenance Plan, Contamination Control Systems*, NIF-5027654 [118].

Requirement: ***Air emissions shall meet the requirements of Section 3.1 (radiation shielding and confinement) for radionuclides and the requirements of the Clean Air Act, (42 U.S.C. 7401) including National Emission Standards for Hazardous Air Pollutants (NESHAP), and state and local air quality management district requirements.***

Evidence:
Projected bounding airborne radiological emissions from the NIF are documented in *NESHAPS Evaluation of the National Ignition Facility,* EMAD09-018 [44], showing compliance with 40 CFR 61, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities. In addition, actual emissions, which are far below this, are reported in the *LLNL Annual Environmental Report [120]*. Air emissions of VOCs are specified in the *Bay Area Air Quality Management District Permit to Operate, Source# 2121*, and compliance is demonstrated through the permit log.

5. SAFEGUARDS AND SECURITY

Requirement: ***The NIF safeguards and security features shall meet the requirements of DOE Security Orders applicable to the LLNL site. These requirements include physical protection of classified data and equipment and items in use and in storage.***

Evidence:
National Ignition Facility Classified Operations Security Plan – SOM-PLN-05-11-007605 [121].

Requirement: ***For the facility security areas and access control, requirements shall be established based on the nature of experiments (i.e., classified or unclassified) being performed.***

Evidence:
Supervisory Control and Data Acquisition (SCADA) Information System Security Plan ID# 6181-SC-L [122].

Requirement: ***The limited areas shall be the target area, target receiving and inspection, final target alignment, classified data acquisition, and office areas where classified computing is performed.***

Evidence:
National Ignition Facility *Classified Operations Security Plan* SOM-PLN-05-11-007605 [121].

Requirement: ***Automated Data Processing (ADP) systems handling classified information shall meet the requirements of DOE Orders for Classified Computer Security Program and Telecommunications: Protected Distribution Systems.***

Evidence:
Classified Distributive Information *Network (CDIN) Plan* NIF5031563 [123].

Requirement: ***The NIF complex shall also meet the requirements for physical protection of DOE property and unclassified facilities, protection program operations, and personnel security, including issuance, control, and use of badges, passes, and credentials.***

Evidence:
NIF Access, Procedure 5.5, NIF-5022192 [124], addresses how NIF complies with requirements for physical protection of DOE property and unclassified facilities, protection program operations, and personnel security, including issuance, control, and use of badges, passes, and credentials.

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6. BUILDING SYSTEMS

6.1 Design Life Requirements

Requirements:

- ***The NIF facilities shall be designed for at least 30 years design life for permanent structures.***
- ***Systems or portions of systems for which that is impractical shall be designed for ease of replacement.***
- ***The performance category for target area and laser structural systems shall be category 2 with a graded approach for other systems.***

Evidence:

- The first two requirements were captured in the Requirements Management System as NIF-5501271-OB [125, 125a]: "All new construction shall be designed for at least a 30-yr. lifetime. Systems or portions of systems for which a 30-yr. life is impractical shall be designed for ease of replacement (i.e., timely, reasonable cost, and consistent with NIF availability requirements established in Functional Requirements and Primary Criteria NIF-1006). Replacement includes removal, refurbishment, and reinstallation of original equipment, as well as the installation of new replacement equipment."
- The third requirement was captured in NIF-5500962-OB [126, 126a]: "The LTAB[6] and OAB[7] shall be designed and constructed per Performance Category 2 (PC-2) as defined in DOE-STD-1020-94 (Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities) and DOE-STD-1021-93. Structure and elements significantly supporting alignment sensitive special equipment shall be designed to meet Performance Category 3 (PC-3) analysis provisions in both LTAB and OAB see Seismic Provisions for NIF- S. Kumpan-NIF-0000214, dated June 21, 1996 [127], and later updated Seismic Provisions for NIF-Stanley Sommer and Madhu C. Kamath – NIF-0000214OB, dated February 3, 1997 [128]. Other facilities shall use a graded approach."
- The structural system requirement is flowed down to the LTAB in NIF-5502071-OB [125, 125a]: "Structural designs for the LTAB shall be performed in accordance with the following standards. See Table 3212 [reproduced from NIF-5502071-OB]."
  - The requirements in Table 3212 were passed on to the A&E firm and incorporated into the designs for the building, conventional facilities, and process utilities. These requirements were also incorporated into the designs beam path infrastructure.

[6] LTAB = Laser and Target Area Building
[7] OAB = Optics Assembly Building

Table 3212. Structural Design Codes and Standards [#128 & 129]

General	International Council of Building Officials, UBC, 1994 Edition. LLNL Special Requirements for Structural Design. DOE Order 6430.1A, General Design Criteria (used for design guidance when no other criteria apply). DOE STD 1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems and Components. DOE STD 1020-94, Natural Phenomena Hazards Design.
Design	American Society of Civil Engineers, ANSI/ASCE 7-93, Code Requirements for Min. Design Loads for Buildings.
Concrete	American Concrete Institute, ANSI/ACI-301. Association of State Highway Transportation Officials (AASHTO).
Steel	American Institute of Steel Construction, AISC Manual M011 Ninth edition.
Seismic Design	Seismic design provisions for NIF are based on information in the NIF Functional Requirements and primary criteria, DOE STD-1020-94, the Uniform Building Code (UBC) and NIF correspondence on NIF-0000214-OB- “Seismic Provisions for NIF”.

6.2 Vibration Requirements

Requirement:

- ***The structural design of these areas shall provide means to effectively isolate this equipment to control vibration within specified displacement and rotation requirements.***

Evidence:

- The requirement is captured in NIF-5501066-OB [130, 130a]: "The LTAB will house vibration-sensitive special equipment. The structural design of the Laser Bays, Switchyards and Target Bay shall provide means to effectively isolate this equipment to control acoustic noise and vibration within specified displacement and rotation requirements. Any component located within the laser bay or target building shall be included in assessments of vibration."
- The flowdown for the NIF primary criteria for beam position on target is provided in Chapter 11 of NIF Laser System Performance Ratings, UCRL-ID-131115, 1998 [131]. There are many references in that document that provide the detailed background for the flowdown. One of those references provides the vibration criteria in NIF-5000543, “NIF Broadband and Narrowband Vibration Criteria” [132]. The criteria in NIF-50000543 have been incorporated into facility hardware as evidenced by the vibration isolation pads for vacuum pumps, HVAC[8] equipment, and other potential vibration sources. The most important evidence that we are meeting this requirement is our ability to align and shoot targets.

[8] HVAC = heating, ventilation, and air conditioning

6.3 Electrical Power

Requirement:

- ***Electric power shall be installed in accordance with NFPA 70, which includes details from the National Electrical Code; IEEE 493, Recommended Practices for Design of Reliable Industrial and Commercial Power Systems; and ANSI C2, the National Electrical Safety Code.***

Evidence:

- This requirement was first captured in NIF-5501035-OB [133, 133a]: "Electric power shall be installed in accordance with NFPA 70, which includes details from the National Electrical Code, IEEE 493, Recommended Practices for Design of Reliable Industrial and Commercial Power Systems, and ANSI C2, the National Electrical Safety Code."
- This requirement was flowed down to the LTAB by NIF-5502101-OB [134, 134a]: "Electrical systems designs for the LTAB shall be performed in accordance with the following standards. See Table 3219 reproduced from [NIF-5502101-OB]."

Table 3219. Electrical Codes and Standards [#135]

– National Electrical Code, NFPA 70.
– Edison Electric Institute (EEI).
– Illuminating Engineering Society (IES) Lighting Handbook.
– Institute of Electrical and Electronic Engineers (IEEE).
– Insulated Cable Engineers Association (ICEA).
– National Electrical Manufacturers Association (NEMA).
– Underwriters Laboratories (UL).
– Lightning Protection Institute (LPI).
– National Fire Protection Association (NFPA).
– LLNL Facility Standards.
– NIF Grounding Plan, L-17346.
– LLNL Procurement Specifications Plan, PSM-E-16490.

- During construction, all electrical work was inspected and accepted as part of the BIS-IMI contract and follow on contracts whose work was managed by Jacobs. Any modifications or additions to the electrical infrastructure are now covered by the BAHJ (Building Authority Having Jurisdiction) process. These inspection processes have keep NIF in compliance with the above requirements.

6.3.1 Voltage Quality

Requirements:

- ***Voltage shall be maintained in compliance with ANSI C84.1, Electrical Power Systems and Equipment – Voltage Rating (60Hz).***
- ***Electrical supply systems shall operate within the limits specified for Range A of this specification.***
- ***Computers shall be protected with low voltage dropouts requiring manual restart.***

Evidence:

- The first two requirements are captured in 5501036-OB [136, 136a]: "Voltage shall be maintained in compliance with ANSI C84.1, Electrical Power Systems and Equipment -Voltage Rating (60 HZ). Electrical supply systems shall operate within the limits specified for Range A of this specification. Voltage occurrences outside these limits should not exceed the Range B limits. These variances should be limited in extent, frequency, and duration."
- The ANCI 84.1 standard states a nominal voltage and a tolerance, the nominal voltages for NIF are 480V, 277V, 208V, and 120V. The range A tolerances for all of these voltages are plus or minus five percent. The range B tolerances are minus ten to plus six percent. NIF has been designed and operates in the range A tolerance band. Plant engineering can measure voltages at any location on NIF to verify if desired.
- The third requirement was captured in NIF-5501037-OB [137, 137a]: "Computers shall be protected with low voltage dropouts requiring manual restart."
- The third requirement has not been directly met. However, the intent of this requirement is to avoid having large transients that occur during power outages. The idea is to sense an under-voltage condition and then remove the equipment from service until the power is restored. The equipment is then restored after all other transients have ceased. Although this requirement has not been met in B581, the server farm for NIF in B490 is on UPS so that the intent of this requirement has been met because the UPS prevents an under voltage condition unless the duration of a power outage is more than tens of minutes.

6.3.2 Standby Power

Requirements:

- ***Standby power shall be available for health, life, property, and safeguards and security loads, including emergency egress lighting, fire alarms and sensors, security systems, and radiation monitors.***
- ***Power for safety and security functions shall be installed and operated according to NFPA 101, the Life Safety Code; ANSI/NFPA 110-1993, the Standard for Emergency and Standby Power System; NFPA 72, National Fire Alarm Code; and other applicable NFPA and OSHA standards.***

Evidence:

- These requirements were flowed down to NIF-5502103-OB [138, 138a] "Standby power will be provided by two diesel generators located on site (see SSDR 1.2.1) and meeting best available control technology (BACT). Standby power shall be distributed at 480 V, 3 phase and 120 V, single phase to those critical loads requiring reliable redundant power supply, such as, Emergency lights, Radiation monitoring system, Fire alarm system, Paging systems, Security systems, Target chamber area negative air pressure control ventilation fans, cryogenic vacuum pumps, Diagnostic Building basement and other DB exhaust. Number, size, and location of the electrical loads on standby power shall be specified and shown on electrical design documents. Automatic transfer and bypass isolation switches and dry-type transformers to transform power from 480-V to 208/120-V shall be provided. Standby power shall meet the minimum requirement of LLNL Facilities Standard PEL-E-16620. Automatic transfer and bypass isolation switches shall meet the minimum requirement of LLNL Procurement Specifications PSM-E-16490."
- Standby power meets the above requirements as evidenced by LEA07-114480 [139] and LEA07-124481 [139a], one line diagram for the standby generators, and the panel schedules related to these drawings.

7. OPERATIONAL AVAILABILITY

Requirement: ***User demands for shot time are expected to be high, therefore, the facility shall be designed for maximum reasonable availability and rapid recovery from unplanned shutdowns.***

Evidence:
The NIF maintenance strategy has been to perform preventative and periodic maintenance of conventional systems (such as power supplies or turbo pumps) and corrective maintenance or as-needed repairs for the laser systems to best maximize facility availability. This maintenance mode has worked well since we have implemented predictive maintenance strategies for many systems, where the maintenance can be scheduled and performed between shots as much as possible. Over the years, the NIF Reliability, Availability, Maintainability (RAM) process has helped improve the overall shot rate of the NIF facility. The NIF RAM process is documented in NIF-0118248.

7.1 Reliability, Availability and Maintainability (RAM)

Requirement: ***The components, systems, and processes that limit overall facility availability shall be identified during the design process through analyses of turnaround times, mean times between failures, mean times to repair, preventive maintenance requirements, etc.***

Evidence:
NIF's RAM process is used to maintain high availability of the facility. The RAM process of gathering, analyzing, and reporting RAM data has helped NIF managers to identify systems that are impacting availability and improve availability through strategies such as:

- Implementing engineering upgrades and retrofits
- Adding functional redundancies
- Implementing key performance metric monitoring to detect maintenance opportunities
- Identifying and implementing maintenance process improvements

The RAM process has helped system engineers develop a more robust and coordinated inspection and repair strategies for those systems that need preventive and periodic maintenance. RAM has also led to the implementation of continuous updating of spare levels and methods for identifying potential training needs. The NIF RAM process is documented in NIF-0118248 [140].

Requirement: *The facility shall be available for three shift operations at least 253 days per year (73% availability).*

Evidence:
In the most recent full year of shot operations for which analysis data is available (from 11/1/2010 to 10/31/2011), the NIF facility was operational just over 290 days, surpassing the 253-day minimum requirement. In this year, 154 successful target shots were conducted.

Requirement: ***The facility shall be available for at least 616 no-yield target shots per year.***

Evidence:
The initial performance requirement for the NIF facility was a facility availability of 70% resulting in 256 days of shot operation in a year. The expectation was to have 3 target shots attempted in a 24-hour period, resulting in 768 target shot attempts per year. With an 80% shot success rate, the NIF was expected to successfully complete 616 no-yield target shots per year.

The NIF facility was operational a little over 290 days for shot operations in a year of shot operations from 11/1/2010 to 10/31/2011, which was the most recent full year of shot operations data available when this analysis was performed—this is a little over the requirement of 253 days of shot operations per year.

On March 5, 2011, we took three RT calorimetry shots, which is an example of a no-yield target shot in NIF, in about twenty-one hours (from 10 a.m. on 3/5/11 to 7 a.m. on 3/6/11), which is slightly better than the 8-hour shot duration expected for these kind of shots.

The current shot success rate is about 94% and is better than the 80% specified in the functional requirements. The shot success rate calculations include all shot impact failures like the Integrated Computer Control System (ICCS), Industrial Control System (ICS), NIF hardware, laser, target, diagnostics and any operational failures.

Given 290 days of facility availability, the demonstrated capability of conducting 3 shots in less than a 24-hours period, and a 94% shot success rate, NIF is capable of meeting the required number of no-yield target shots per year.

Requirement: ***The project shall provide the initial set of maintenance equipment, consisting of at least one unit of each piece of equipment that is required to maintain and operate NIF. Future addition of more units of maintenance equipment shall not be precluded***

Evidence:
Adequate spares are available for maintenance equipment such as forklifts, transporters, and cranes. For the laser systems, initial spares have been defined and are continuously updated based on operational failure rates; our plan is to have at least one full spare for every line-replaceable unit. NIF facility availability has not been impacted by spares unavailability during any of the previous years of operations. Our process for determining spares involves incorporating modeling results based on our current operational experience of failure rates and recovery times. Optics production has been calculated based on the shot plan.

Requirement: ***The lasers shall perform within specification (e.g., laser energy, beam balance, pointing accuracy) on at least 80% of all shots.***

Evidence:
NIF laser systems are highly reliable and are expected to perform within specifications. We have yet to retake a shot because of laser energy, beam balance, or pointing accuracy issues. The current laser availability (shot success rate) is over 95%—far better than the specification of 80%. The laser availability rate includes ICS[9] and ICCS[10] failures, plus any failure that is not due to target, diagnostics, or operator error.

7.2 Recovery Time

Requirement: Because of its importance to the DOE, the NIF shall be designed to survive any abnormal event, including accidents and natural phenomena, expected to occur more frequently than once in 2000 years. The time required to recover from such events is allowed to vary in accordance with the probability of occurrence. Maximum recovery times are specified below.

[9] ICS = Industrial Control Systems (e.g. beampath utilities)
[10] ICCS = Integrated Computer Control System

Probability of Occurrence Per Year, P	Maximum Recovery Time
P = 1	**24 hours**
$1 > P \geq 10^{-2}$	**1 week**
$10^{-2} > P \geq 5 \times 10^{-4}$	**3 months for laser, target, and associated building structures** **6 months for support systems** **6 months for support systems**

And

Requirement: ***The probabilities of occurrence listed in DOE-STD-1020-94 and DOE-STD-1021-93 shall be utilized for natural phenomena.***

Evidence:
Recovery times for NIF operational failures are tracked and well understood and they are typically fractions of a shift. An earthquake during shot operations required one shot shift, or about 12 hours, for recovery of data. We expect an event such as a low magnitude (weak) earthquake (a potentially high probability of occurrence event for northern California) could affect cryogenic layer formation or beamline alignment, or perhaps cause damage to optics that may require replacement. The expected recovery time for these events is about 24 hours depending on the experiment.

For lower probability events, we put together a list of off-normal failures that are unlikely to occur but have a very high impact on the NIF operational availability. Examples of these events include target positioner (TASPOS) water line rupture, outgassing of borated polyethylene from cryogenic target positioner (CryoTARPOS) boom plug, or Master Oscillator Room (MOR) rack cooling system failure. On average, these failures have affected NIF operations from one day to two weeks.

Events with extremely low probability of occurrence include natural disasters such as a very strong earthquake, high winds, or flood damage. A significant earthquake, the most likely, low probability of occurrence event for the NIF facility has been addressed in the document NIF-0000214-OB, Seismic Provisions for NIF [127].

The NIF Shot Operations Manual (NIF-5018506) [143] provides general policies governing administrative and operational practices related to shot operations. This includes general responses for major facility off- normal conditions such as fire, earthquake, oxygen deficiency, and crash button actuation. Operational Safety Procedures (OSPs) and operating procedures may include additional detailed steps, as required.

The NIF Maintenance Plan (NIF-5018526) [144] describes the system's equipment and assets, boundaries, interfaces to other systems, and the maintenance approach including failure modes and general responses for major system off-normal conditions.

Requirement: ***Standby power shall be available to preserve process continuity in cases designated by the NIF Project and specified in the System Design Requirements (SDR). Neither uninterruptible power systems nor standby power is required for the computer systems.***

Evidence:
See evidence provided for NIF PC&FRs, Section 6.0 Building Systems, 6.5.2 Standby Power [138].

8. DECONTAMINATION AND DECOMMISSIONING

Requirement: ***The NIF design shall meet the site-specific requirements.***

Evidence:
An initial Decommissioning Plan for NIF, NIF-0001670, was developed during the conceptual design phase. This was later updated and re-issued as *NIF Decontamination and Decommissioning Plan, Fiscal Year 2001 Update*, NIF-0071441 [146]. Factors identified were subsequently incorporated into the design and operation of the NIF.

Requirement*: The NIF shall be designed for periodic cleaning of the interior of the test chamber to maintain tritium levels on interior surfaces as low as reasonably achievable.*

Evidence:
Periodic cleaning of the interior of the target chamber is accomplished via a "vent and pump" process. See *Operation of the Target Area Vacuum System (TAVS),* NIF-5013152 [147]. This process is required to be executed prior to accessing contaminated volumes, including the Target Chamber, per OSP 581.11, *NIF Laser System Installation, Commissioning and Operation*, Appendix L, *Radiological and Be Hazards and Controls*, NIF-5017298 [7].

Requirement: ***The NIF design shall include considerations that will allow for cost-effective future decommissioning of the structures and equipment.***

Evidence:
An initial Decommissioning Plan for NIF, NIF-0001670, was developed during the conceptual design phase. This was later updated and re-issued as *NIF Decontamination and Decommissioning Plan, Fiscal Year 2001 Update*, NIF-0071441 [146]. Factors identified were subsequently incorporated into the design and operation of the NIF.

Requirement*: A plan for NIF Decontamination and Decommissioning (D&D) shall be developed in accordance with DOE Order 5820.2A, Radioactive Waste Management*.

Evidence: An initial Decommissioning Plan for NIF, NIF-0001670, was developed during the conceptual design phase. This was later updated and re-issued as *NIF Decontamination and Decommissioning Plan, Fiscal Year 2001 Update*, NIF-0071441 [146]. Factors identified were subsequently incorporated into the design and operation of the NIF.

Requirement: ***A D&D assessment shall be made during conceptual design to ensure that features and measures are incorporated in NIF to simplify D&D.***

Evidence:
An initial Decommissioning Plan for NIF, NIF-0001670, was developed during the conceptual design phase. This was later updated and re-issued as *NIF Decontamination and Decommissioning Plan, Fiscal Year 2001 Update*, NIF-0071441 [146]. Factors identified were subsequently incorporated into the design and operation of the NIF.

9. QUALITY ASSURANCE

Requirement: ***The NIF Quality Assurance Program shall meet the requirements of DOE Order 5700.6C, Quality Assurance.***

Evidence:
The NIF&PS Directorate has a Quality Assurance Program in place that meets DOE Order 414.1D. DOE Order 414.1D replaces DOE Order 5700.6C referenced in NIF-0001006-OE. The NIF&PS Directorate Quality Assurance Plan (DQAP) (NIF-5021183) [148] flows down from ES&H 41.1, which flows down from DOE O 414.1D. NIF's DQAP can be found on the Team NIF Internal Procedure website.

Requirement: ***As specified in this DOE Order, a graded approach using quality levels based on risk assessment shall be spelled out in the NIF Quality Assurance Program Plan and utilized throughout the project.***

Evidence:
The NIF & PS Directorate Quality Assurance Plan outlines NIF's graded approach using quality levels based on risk management (Page 6) of the NIF&PS DQAP.

Requirement: ***The QA Program Plan shall cover all aspects of the NIF Project in a phased implementation, beginning with conceptual design.***

Evidence:
NIF-0000618 National Ignition Facility Quality Assurance Program Plan Revision 1 released September 1996 [149].

Introduction (page 2): Purpose and Scope of the QA Program Plan

"This QA Plan incorporates and supplements applicable QA Program requirements of DOE Order 5700.6C and LLNL QA Plan M-078, and the Laser Directorate QA Plan L-18724."

Section 6.0 Design (page 17):

This section addresses DOE Order 5700.6C requirements and the NIF Procedures used to implement these.

-NIF Procedure 6.1 System Design Requirements [150]
-NIF Procedure 6.2 Interface Control Documents [151]
-NIF Procedure 6.3 Engineering Drawing Standards and Controls [152]
-NIF Procedure 5.1 Engineering Design Reviews [153]

10. ORDERS, CODES, AND STANDARDS

10.1 Orders

Requirement: ***The NIF shall be designed and constructed in full compliance with DOE Orders accepted as part of the Work Smart Standard process and federal regulations. Exceptions shall be limited to those cases where the project has formally requested and been granted either an exemption or a finding of equivalency by Headquarters.***

10.2 Codes and Standards

Requirement: ***Additional references identified during the developmental phases shall be formally cited and controlled in system and subsystem design requirements documents and specifications through the Project Change Control Process.***

10.3 Applicable Orders, Codes, and Standards

10.3.1 DOE Orders

10.3.2 National Consensus Standards

Requirement: ***The NIF Project shall comply with the following national consensus standards, as noted elsewhere in this document:***

- ***ACI 301 - 1996, Specifications for Structural Concrete for Buildings***
- ***ANSI C2 - 1993, National Electric Code***
- ***ANSI C84.1 - 1989, Electrical Power Systems and Equipment−Voltage Rating (60 HZ)***
  ……………………………….(see original document [0], Section 10, pp 17-20 for complete list)

In addition to complying with these specific standards, the NIF Project shall utilize applicable and appropriate national consensus codes and standards in the design, procurement, fabrication, installation, construction, inspection, and testing of structures, systems, and components, per DOE Order 1300.2A. Codes, standards, and guides of recognized technical and professional organizations, such as those in the following list, shall be applied as appropriate to NIF materials and workmanship:

- ***AA Aluminum Association***
- ***AASHTO American Association of State Highway Officials***
- ***ABMA American Boiler Manufacturers Association***
  ……………………………….(see original document [0], Section 10, pp 17-20 for complete list)

This entire Section is grouped together and covered by the evidence given below. See also responses to and evidence provided for the other Sections of this document where specific DOE Orders, Government Regulations, and National Consensus Standards are called out in the context of the subject matter for that Section.

Evidence:
DOE Orders, Government Regulations, and National Consensus Standards were implemented by the NIF Project through the applicable NNSA-reviewed LLNL policies and procedures, NIF-specific policies and procedures, and through technical requirements specified for NIF design, construction, and fabrication, consistent with the process defined in the Project Execution Plan. These requirements were implemented with the support of the related subject matter experts and disciplines at LLNL such as industrial safety, radiological protection, fire protection, environmental protection, quality assurance, mechanical and electrical engineering, physical security, computer security, facilities and infrastructure. Conformance with these requirements was reviewed and validated by the

NNSA NIF Federal Project Director's staff as a part of the open and transparent access to the execution of the NIF Project.

- National Ignition Facility Project, Transition to Operations Plan [154], Prepared by NIF Project Division (NA123.2) Staff and Approved by Livermore Site Office, Assistant Management for Operations management, Assistant Manager for Safeguards and Security, Technical Deputy Manager, and NIF Federal Project Manager, June 2008.
- National ignition Facility Completion Report, NIF-0115688, September 30, 2009 [155], that includes summaries of and reference to Project Readiness Reviews and NNSA's Readiness Assessment, Approval of Critical Decision, CD4, for NIF Project Completion Memorandum signed by NNSA Administrator, T. D'Agostino, and Laser Performance Completion Letter.